A Collaborative Approach to Lifecycle Management: An Engineering Perspective

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ABSTRACT

Engineering is usually more concerned with the creation of information rather than the lifecycle management of it. A recent shift in the emphasis to the reuse of engineering and product information to shorten development times, however, has increased the importance of lifecycle management in the engineering process. While archivists are generally concerned with managing information in support of secondary users, lifecycle management from an engineering perspective focuses on reuse and adaptation. Many of the techniques and capabilities developed by archivists are also useful in meeting the needs of engineers and other primary uses. In this paper, we will discuss how the partnership formed between the engineering and archival disciplines at the Jet Propulsion Laboratory (JPL) is working to improve lifecycle management for all users. We will call upon examples from JPL flight Projects, including the Mars Pathfinder Mission.

OVERVIEW OF FLIGHT PROJECTS AT JPL

JPL's primary mission is planetary exploration – to do what no one has done before. We do this by designing, building, and operating planetary spacecraft and instruments. Since we are building "first of a kind" missions that must work well, meet their objectives, and take advantage of unique opportunities, JPL has relied on the application of the collected wisdom, experience, and expertise of our professional staff – our corporate knowledge - in order to anticipate problems and apply innovative solutions. In the past, our corporate knowledge has been shared between missions by moving people to work on successive projects. When a person completed his or her assignment on one flight project, they would move on to the next one, taking their files, notes, and lessons learned with them.

In the age of better, faster, and cheaper, we need more methodical, reliable, and robust ways of capitalizing on our corporate knowledge that rapidly disseminate good ideas across multiple projects. The Develop New Products (DNP) reengineering effort is redesigning the way we build spacecraft and operate missions. One of the cornerstones of the new process is reuse and adaptation of previous work and the sharing of information while projects are in progress. Rather than relying solely on the reassignment of personnel from one project to the other, the DNP effort is investigating ways in which valuable information can be shared while the potential for reuse and adaptation is highest.

The working environment of flight projects, unfortunately, often presents an obstacle to capturing engineering and other project-related information. Sharing information requires that the engineer, scientist, or other professional take extra steps to ensure that the information is accessible, in a shareable format, and includes enough background information to assure that it can be interpreted in context. Given that most flight projects function in an environment characterized by tight deadlines, extreme time pressure, and high-stakes milestones, the engineer is often faced with an overwhelming task just to complete his or her job. The additional workload associated with sharing information has a much lower priority.

Contributing to this lower priority is the question of how valuable this information is. If the person responsible for generating the information doesn't perceive that it is important to capture it for others to use, then they will naturally be less inclined to make the extra effort necessary to do so. This perception has been fueled in the past by the difficulties associated with finding, accessing, and interpreting information. In many cases, it has been significantly easier to reinvent than to find something that could be reused or adapted. Other factors inhibiting the reuse of information include obsolescence, incompleteness, lack of context, and questionable heritage. These and other concerns are being addressed in the reengineering of the DNP process. A valuable partnership with a professional archivist has provided additional insights and techniques which have been incorporated into the DNP approach to knowledge management. The remainder of this paper addresses areas where we have benefited from this partnership with the archival community as well as some disconnects between the engineering and archival disciplines which will serve as fertile ground for future evaluation.

LESSONS LEARNED FROM ARCHIVISTS

Processing a collection to be archived involves the application of a number of techniques for organizing, inventorying, and cross-referencing materials. It also involves using personal and professional judgements about what information is important and how the different parts of the collection relate to one another to create the bigger picture. For engineers working on a project, the useful life of the information they create generally ends when the project ends. Archivists, on the other hand, traditionally begin their work after the project has ended and they see a much longer useful life for the information. Using concurrent engineering practices, project teams have been extended to include professionals from multiple disciplines that have featured roles at different times throughout the project. The purpose is to address downstream issues early in the project and therefore avoid problems and take advantage of opportunities. Extending this concept to include archivists provides the opportunity to address the lifecycle concerns of the information. By looking at 1) what archivists considered important in retrospect 2) how they organized and processed the collection, and 3) specific techniques they used in the processing of the collection – we identified steps that could be taken while the project is in process which would greatly enhance their usefulness – and which could speed up the processing of the collection at the end of project.

There are five major lessons learned during the engineering-archivist collaboration on the DNP reengineering team. The first is that engineering and project information truly is valuable to other users throughout the life of the project and beyond. Applying the concept of "secondary users" enabled us to broaden our definition of potential users of information and increased our sensitivity to their needs when creating and processing information. The second lesson was the importance of looking at project information as a whole, rather than just as individual pieces. This gestalt view provides valuable insights into how people did their jobs, the information that they considered important, and how ideas, processes, and relationships evolved throughout the lifetime of the project. From a narrow, individual document perspective, a collection may contain many redundant pieces of information. From a broader, big-picture perspective, however, a richer view into the history of the project can be constructed which uses these redundancies.

Professional judgement needs to be applied in determining what parts of the collection are important to keep. The JPL Archives has processed numerous flight project collections and based on the results, we were able to jointly develop a set of guidelines which will enable a project to annotate items as they are being developed. There are several reasons to keep an item, for example: it's a legal or contractual requirement, it represents the first time a new concept appeared, it provides a summary of a phase of the project, or it lays the groundwork for a major shift in direction. The third lesson is that understanding these reasons and incorporating an "in-process assessment" of their value when they are created will reduce the post-project processing, and provide value context information during the lifetime of the project.

The fourth lesson, and one which is counter-intuitive to most engineers, is that you can throw things away. Engineers are notorious pack-rats and find it very difficult to part with materials because they "might be useful someday." The archiving community, however, routinely must reduce the size of collections to a manageable level without significantly impacting its scope and content. To do this, they have developed criteria to determine what to throw away. Many of the materials generated on a project are redundant, so it is possible to cull the collection to reduce the amount of material that needs to be carried forward. For example, an engineer may often be called upon to give the same presentation multiple times to different audiences. The content of the presentation may evolve over the course of time, but the presentations are basically the same. The many copies of the presentation can be replaced by a single copy incorporating the major ideas and a list of the audiences to whom it was presented. There are other examples such as cumulative financial data, mailing lists, and organization charts. By applying archiving techniques used to cull collections while maintaining the pertinent information, we have found easier ways of managing our information during the lifetime of the project.

Finally, part of processing a collection for archiving is the creation of finding aids, information about the collection and items in the collection which enable someone to search and identify items of interest. At the most basic level, this would consist of an inventory of materials. However, finding aids can include other detailed information that significantly increase the usefulness of a collection. We have whole-heartedly adopted this concept. As a minimum, the inventory is created as the collection is generated. In addition, we solicit additional information about what the item is, why it was created, and other meta information which makes it easier to find things during the lifetime of the project, and which serves as a starting point for processing at the end of project.

The partnership between engineering and archiving resulted in many improvements in the way we handle our project information which benefit both communities. By considering the role of the archivist post-project, we were able to make minor changes in work for the people creating the information which should greatly reduce the difficulty of archiving the collection. These changes, however, also benefit the project personnel by providing greatly improved organization, accessibility, and context of their information while the project is underway. The challenge was to balance the lifecycle issues with the additional workload needed to address these issues and come up with workable, economic solutions.

Many of these concepts were used on the Mars Pathfinder project. In some cases, we learned from the new approaches they were using. In others, we were able to influence their processes based on our partnership. The following section provides an overview of pertinent activities on Mars Pathfinder.

MARS PATHFINDER PILOT EXPERIENCE

On July 4, 1997, the world watched in wonder as the Mars Pathfinder landed on the surface of Mars. For the next several months, the captivating mission provided new and amazing insights into the Red Planet through its cameras, instruments, and the Sojourner Rover. In addition to its exciting mission and innovative engineering approach, Pathfinder also plowed new ground with respect to the process of how JPL built and operated a flight project. Because it was also pathfinding the process of "better, faster, cheaper," the project manager placed a high priority on capturing information relevant to the engineering process. This led to changes in the types of information that ~~was~~ were collected, the expected contributions from team members, and the acknowledgement that collecting this information for future use was important. Mars Pathfinder agreed to pilot several of the concepts being developed by the engineering-archiving partnership.

The focal point for project information on Mars Pathfinder (MPF) was the MPF Project Library. The MPF Project Library served as a single, centralized collection point for project documentation. The pathfinding philosophy of the project extended itself to how the library was operated. For example, unlike other project libraries, the MPF Project Library accepted any document that a member of the project felt was important. In addition to the usual status reports and project planning documents that are normally found in a project library, the MPF Project Library also captured presentation materials, draft papers, annotated materials, and project artifacts. These documents didn't have to go through rigorous review processes. Even imperfect, casual documentation was accepted, catalogued, and included as part of the collection. Because of this relaxed approach, the MPF Project Library captured materials which provide a unique view into how this very important project operated, how ideas developed, and materials that otherwise would have disappeared into people's filing cabinets.

In addition to project documentation, the Mars Pathfinder Project also put a concerted effort into capturing the day-to-day engineering and operations data. A flight project is expected to capture, process, and make available the science data that it collects. The Planetary Data System (PDS), for example, is a NASA-wide information management system that serves as an archive for planetary science data. The engineering data, which includes products such as command sequences and operations plans, is generally not treated with the same rigorous attention as the highly valuable science data. Mars Pathfinder, however, decided to capture this ancillary information in a way which will provide historical insight into the operations of the project.

The Navigation Ancillary Information Facility (NAIF) was designated as the location which would archive the engineering data. The engineering data consists of spacecraft navigation data, spacecraft telemetry data, the mission planning data, and ancillary supporting data. Standards used by the Planetary Data System were used, where appropriate, to capture this information. Other data (e.g., raw telemetry data) was saved in the original file format due to cost constraints and the lack of available standards.The navigation data consists of all of the orbit determination solutions, which were used for trajectory correction maneuvers and the entry decent and landing operations, along with the maneuver design files and the parachute deploy algorithms.

The spacecraft telemetry data is all the data sent back to the earth from the spacecraft. This includes data from telecommunications, power, attitude control, thermal and propulsion subsystems as well as the raw science data. This data comes in two forms, packet data and channel data. The packet data files are binary files and have been archived along with their file definitions and ASCII summary description files. The channel data are stored as ASCII comma delimited files. In order for these files to remain accessible, additional documentation describing the format and how to read these files was included. It was very important to save this raw data not only as ancillary information for the science data and the historical perspective but also as the only true raw science data set. The Engineering Data Records (EDRs), which contain the science data archived within the PDS, have had some minor processing done to them.

The mission plans, as represented in science and engineering command sequences, were archived using PDS standards. The science and engineering sequences were developed separately and then integrated into a form which could be saved to see what was commanded to occur on a given day. During the cruise phase of the mission this worked well. However, this could no longer be maintained during the flurry of surface activities, when engineers did not have enough time to complete the extra step of integrating the sequences. Additional information had to be incorporated to account for communication errors which resulted in incomplete uplink communication sessions and last minute sequence updates based up telemetry. This has caused the need for post-operations development of these archival products by project personnel.

One new product generated by Mars Pathfinder was the Experimenter's Notebook (ENB). This was an on-line software tool which was used to collect and display pertinent science and engineering data on a daily basis during operations. Files enetered into the ENB were translated into formats supported by the SPICE Tool Kit (a PDS-supported format for archiving). These files included the Rover up- and down-link reports, meeting notes from the science working group, and the flight director and communications engineer's logs. This collected all the information needed to identify what was planned, what actually occurred, and what kinds of problems were encountered. Saving this information benefits the Pathfinder engineers, as well as engineers on future projects, because of the potential for reuse. It also benefits the archiving process because the information is collected in a way which provides a bigger picture.

The Mars Pathfinder Project made a special effort to capture their project information and engineering data as it was being created in order to support more efficient operations of the project – and to provide a legacy of information on the project for those who follow in its pathfinding mission. Several of the ideas gained through the engineering-archiving partnership were tested on the Pathfinder project to ensure that they met the needs of a flight project, while also addressing the lifecycle issues. This additional partnership, which brought in the element of the engineering data, provided a unique opportunity to evaluate many of the concepts in a real-life situation, under severe time constraints. The lessons learned through pilot activities with Mars Pathfinder provided valuable insights and improved the overall approach.

DISCONNECTS BETWEEN DISCIPLINES

The engineering-archiving partnership provided many valuable lessons and greatly enhanced our efforts to improve the way we do our flight projects. There were, however, some areas where the interests of the disciplines diverged. The largest disconnect was in the area of paper vs. electronic information. For improved accessibility, searching, and reuse, the engineering community has moved into a primarily electronic environment. While we still rely on paper to do the job, the information is generated electronically, stored electronically, shared electronically, and needs to be accessible electronically even after being archived. In our interactions with the archive community, we found a heavy bias toward paper which isn't sufficient to meet the needs of the engineering community.

A second area of controversy is the selection and enforcement of standards. From an engineering perspective, the most valuable format for the information is the native format. This increases our ability to reuse the information and allows us to use the tools we are comfortable with to manipulate the items. For cross-platform compatibility, the next most valuable form is a simple, web-accessible format such as HTML, ASCII, or PDF. Documents created in other applications can usually be easily converted to one of these standards using simple desktop software. Other, more robust standards, e.g., SGML, were supported by professionals in the document management arena. While these standards are intended to extend the long-term accessibility of the information, the tools for generating and modifying documents in these formats are not readily available to the community of people generating documents. Based purely on the pragmatics of reuse, any standard which can't support easy creation and modification is not going to meet the needs of the engineering community. We also had a disconnect with regards to standards for meta-data. In an ideal situation, we would want to collect as complete a set of meta-data as possible. However, this places an unreasonable demand on the engineers without providing any significant benefits. To be fair, the selection of standards is also controversial within the engineering community and will continue to be so for many years to come.

Finally, a third disconnect lies within the self-definition of what an archivist is and does. In our partnership, the archivist became an integral part of the design team and worked proactively to apply the techniques and expertise of her discipline to meet the engineering challenges. In some respects, this greatly broadens the professional domain of archivists, moving them out of the neutral observer and processor mode, and into an active partnership with the creators of information. This adds a new dimension to the archiving profession – that of archivist as designer and shaper of collections. Many in the archiving community seem to be uncomfortable with this type of change, and challenge whether an archivist performing this function is truly an archivist. This is an issue which needs to be resolved within the archiving community.

SUMMARY

The partnership between the engineering and archiving professions at the Jet Propulsion Laboratory has resulted in significant improvements to the lifecycle management of flight project information. Concepts, methods, techniques, and expertise from the archiving discipline have been adapted to support the in-progress capture, management, and processing of large collections of project information. The benefits have been two-fold, improving the flow of information during the lifetime of flight projects, and improving the archiving of the information at the end of the project. Many of these concepts were successfully used on the Mars Pathfinder project and will become part of the standard way of doing business for future flight projects.

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